Hawaii's Terrestrial Ecosystems: Biological Problems and Economic Prospects

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The concept of an ecosystem may be interpreted in a variety of ways. In the most general sense, an ecosystem comprises the sum total of the biotic constituents and the physical (non-living) environment of an area. From a functional point of view, scientists frequently define an ecosystem as any area containing life with a boundary through which the input and output of energy and materials can be measured. Parameters usually measured within an ecosystem include the quantity and distribution of chemicals, the climatic and physical range of conditions, the availability and distribution of energy, and the number and kinds of organisms and their distribution within the ecosystems.

The ecosystem concept as a whole can be applied to different size levels of biogeoclimatic organization in the biosphere, ranging, for example, from a single human body with all its associated bacteria, fungi, parasites, clothing, food intake, etc. to the entire earth, including radiant energy from the sun and its atmospheric, lithospheric, and hydrospheric components.

Ecological studies of the interrelationships between organisms and their environment, usually focus on an area or region which lies somewhere between these extremes of size and complexity. Biologists, ecologists, and biogeographers often refer to relatively expansive ecosystems or large parts of the earth's living environment which are generally characterized by similar types of biological communities as biomes (e.g., tropical rain forest, desert, grassland, deciduous forest, coniferous or evergreen forest, and alpine tundra).

An examination of the arrangement of the earth's major ecosystem or biome types reveals a very generalized, yet distinct and comparable spatial distribution, both latitudinally and altitudinally. In other words, along a gradient of increasing latitude, we encounter ecosystems basically similar in kind and distribution to those we find along a gradient of increasing altitude.

Thus we may observe the same or basically similar ecosystems or biomes going from the equator to the poles as we would going from the base to the top of a high mountain range. This kind of relationship is, of course, a general one and does not take into account a number of interesting aspects of the world's distribution of ecosystems. However, it will serve as a basic framework for reviewing and perhaps under-

standing the ecological adaptations of many organisms native to or naturalized in the high islands of the Hawaiian archipelago.

TERRESTRIAL HAWAIIAN ECOSYSTEMS

Fundamentally there are two kinds of islands: (1) continental islands, which were once connected to a continental land mass; and (2) oceanic islands, which were never connected to a continental land mass. Although some people in the past have postulated former land bridges connecting the Hawaiian Island chain with the continents of Asia or the New World, modern oceanographic research has demonstrated that the Hawaiian Islands are oceanic and therefore have always been separated from a continental land mass. This is a very important point to keep in mind, since one of the outstanding features of Hawaii, affecting both its biological and cultural evolution, is its extreme geographical isolation.

In fact, the Hawaiian Island chain is one of the most isolated archipelagos on earth, approximately 3,000 miles from Japan, 2,400 miles from California, and 1,000 miles from any other significantly large island in the Pacific Ocean.

In addition to their isolated location, the Hawaiian Islands are small in size when compared to other "islands" like New Guinea or New Zealand. The total land area of all Hawaiian Islands are relatively young, but variable, in terms of their geologic age (ranging in age from about 1 to 25 million years).

Yet, although some types are quite limited in their spatial distribution, the archipelago contains a vast array of different ecosystems. Native Hawaiian ecosystems include the coastal strand, lowland dry forests, moderately humid forests, wet rain forests, ponds, lakes, marshes, swamps, estuaries, freshwater streams, bogs, sub-alpine parklands, and alpine stone deserts.

EVOLUTIONARY INVESTIGATIONS OF HAWAIIAN TERRESTRIAL BIOTA

It is well known that the distribution and adaptation of plant and animal species in the remote Galapagos Islands had a profound impact on the ideas and theory construction of Charles Darwin. Based on his observations of the native biological specimens collected in the Hawaiian Islands, Darwin realized the potential importance that the Hawaiian Islands offer for evolutionary research, an importance that is greater than that of the ecologically less diverse Galapagos archipelago.

From a scientific perspective, the Hawaiian and Galapagos Islands represent microcosms of the planet earth, and thus have and still can provide us with insights into ecological and evolutionary processes affecting life in the biosphere. Indeed the terrestrial ecosystems in both archipelagos have presented an important challenge to ecologists ever since these scientists first comprehended the unique and revealing characteristics of island ecosystems and their component species.

Amateur, and later professional scientists have long recognized the Hawaiian Islands as a natural laboratory for investigating the living systems and dynamics of biological phenomena. For example, John Thomas Gulick, a 19th century naturalist working independently in Hawaii nearly 'scooped' Darwin in his formulation of a Theory of Evolution.

The useful lists of plants, insects, shells, and birds and the influential speculations developed by nineteenth century resident investigators in Hawaii such as Gulick, William Hellebrand, Wesley Newcomb, and Thomas Blackburn helped focus international scholarly attention on the unique Hawaiian biota, especially in terms of how these endemic organisms illustrate the crucial role that geographical distribution and isolation play in Darwin's evolutionary concept of inheritance from a common ancestor. Darwin, himself, called for the production of a comprehensive description of the Hawaiian flora as well as in depth examinations of the native fauna in the Hawaiian Islands. Darwin's plea was repeated by a number of other interested naturalists during the last century.

More recent studies of terrestrial ecosystems in Hawaii have also contributed significantly to our understanding of how island ecosystems differ from continental ecosystems, and have allowed researchers to make recommendations for land management and the conservation of natural resources in the state. These studies are important for Hawaii, as well as other parts of the world, because of man's widespread, often severe, disruption of native ecosystems. It is important to point out here that ecosystem disturbances caused by human activity have been especially pronounced on oceanic islands such as Hawaii.

Several studies have shown that the stability of many terrestrial Hawaiian ecosystems is severely decreased when they are invaded by species introduced by man. For example, (1) several populations of native birds probably decreased significantly due to introduced diseases such as avian malaria; (2) exotic feral hoofed animals have caused profound changes in both dryland and wet ecosystems; (3) a number of introduced plants have become established in our ecosystems and, by successful competition, have replaced native species; (4) introduced predators may drastically reduce or cause extinction of ground nesting birds such as the various species of native flightless rails and the state bird, the Nene goose.

Unfortunately, the Hawaiian Islands have the dubious distinction of ranking second only to the Mascarene Islands in the Indian Ocean, in the numbers of plants and animals that have become extinct in recent times, as well as the quantity of endangered and threatened species that still exist.

While only relatively small in total land area, the Hawaiian Islands have had more native species go extinct than all the continental United States combined. It is estimated that only about 10% of the native forest in Hawaii still survives intact today. And, for the most part, it is in these remaining native forest areas that the endangered and threatening endemic flora and fauna can yet be found.

ECONOMIC PROSPECTS AND THE VALUE OF THE NATIVE HAWAIIAN ECOSYSTEMS

It is unfortunate that decision makers in the State of Hawaii appear to be largely unaware of the international contributions that our scientists have been making in the field of ecosystem analysis and probably more importantly in evolutionary biology. These same decision makers seem to be equally uninformed about the economic value of Hawaii's native ecosystems and their component flora and fauna which must serve as the ecological resource baseline upon many of the significant biological studies are, and will continue to be, dependent. It is very important to recognize that evolutionary science is usually non-consumptive of the natural ecosystems themselves.

In light of these considerations, it is a regretable fact that the native ecosystems and endemic species of Hawaii (as in many other oceanic island environments) are under increasing pressure from consumptive land use activities such as ranching, forestry, browsing by huntable feral mammals, and in some cases, from urban development.

Although the native ecosystems and the endangered species of Hawaii are often characterized as having insignificant value outside of the realms of aesthetics, nature appreciation, and perhaps, education, they do have hydrological, genetic, ecological, and cultural importance. We may even assert that the native ecosystems and their component species represent one of the more economically valuable natural resources in the Hawaiian Islands, especially if we consider that millions of dollars are put into the Hawaiian economy for expenditures related to watershed, tourism, recreational, aesthetic, and scientific interests (see Table I). Furthermore, this valuable cumulative resource requires little financial input, other than conservation of what remains of the unique native ecosystems and their parts. And, perhaps most importantly, this resource is not limited to a short term value; it can be "harvested" in virtual perpetuity."

ECONOMIC VALUE OF EVOLUTIONARY RESEARCH IN HAWAII

Recently a catalog of investigators studying the evolution of Hawaiian terrestrial organism has been compiled by a University of Hawaii zoologist. This catalog lists the money coming into the State of Hawaii which has been generated as a direct result of the uniqueness of our native terrestrial ecosystems and the component species. This incoming money has been spent largely to support research and to maintain native ecosystems, botanical gardens, and museums. It should be noted that the figures compiled represent gross underestimates of these monies since replies had not yet been received from such organizations as the National Science Foundation (for a list of mainland investigators working in Hawaii), the Pacific Tropical Botanical Gardens (Kauai), Foster Gardens, Hawaii Malacological Society, and the Hawaiian offices of several federal agencies including the Office of Endangered Species, U.S. Fish and Wildlife Service, the Army Corps of Engineers, the U.S. Navy, the U.S. Marine Corps, and the Animal and Plant Health Inspection Service of the USDA (all of the above agencies employ biologists).

In summary it should be underscored that the total of these monies coming into the state only includes figures for the last four years and are exclusive of pending funds. Moreover, these monies are a grossly underestimated indication of the economic value that the native ecosystems and their component parts have and should most definitely continue to provide for the State of Hawaii. For aesthetic, scientific, recreational, cultural, genetic and economic reasons the native life of the land should be perpetuated in righteousness.
Aloha 'aina.

Table I: Monies coming into the State of Hawaii for Evolutionary Investigations of Hawaiian Terrestrial Biota (including Evolution, Ecology, Systematics, and Population Genetics) for the period 1977 through 1980.

1.	Zoology Department, University of Hawaii	$252,873 (pending)
2.	General Science Department, Univ. of Hawaii	$25,300
3.	Botany Department, University of Hawaii	$623,188
4.	Physiology Department, University of Hawaii	$64,000
5.	Genetics Department, University of Hawaii	$444,234
6.	Entomology Department, University of Hawaii	$91,000
7.	Miscellaneous, University of Hawaii	$14,960
8.	Bernice P. Bishop Museum	$2,363,326
9.	Lyon Aboretum	$237,751
10.	Hawaii Audubon Society	$60,398 (income only)

Grand Total (for 1977-1980 only and exclusive of pending funds) = $3,924,343